

Subseasonal prediction of wintertime North American surface air temperature using the MJO signal

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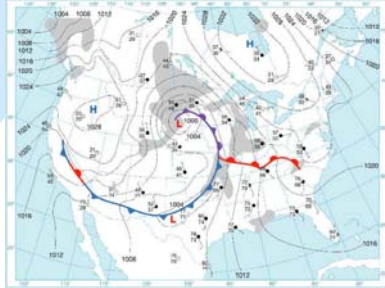
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Outline

- 1) Subseasonal Prediction & the MJO
- 2) The Empirical Model
- 3) Comparison with GEM
- 4) Summary

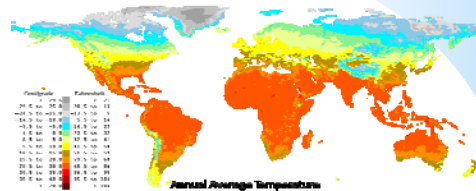
What is Subseasonal Weather Prediction?

Subseasonal Prediction (between 2 weeks and 2 months) lies between 2 regimes ...



Weather Prediction

- Out to 10 days or so
- Initial conditions



Seasonal Prediction

- On the order of months
- Boundary conditions

1) Subseasonal Prediction & the MJO

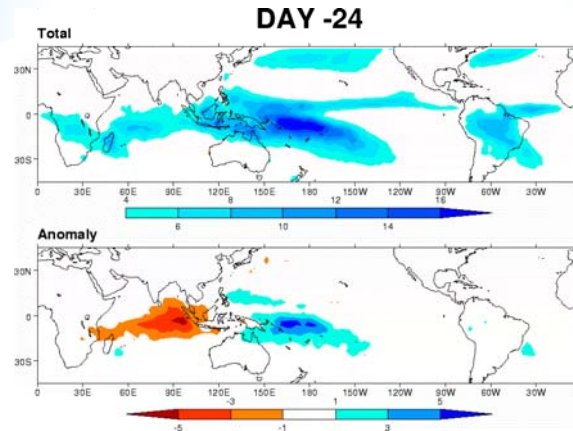
What is Subseasonal Weather Prediction?

- Both initial and boundary conditions have to be accounted for in the case of subseasonal prediction
- Increasing interest in the subseasonal problem reflects a certain maturity in the more traditional "weather" and "climate" problems (Waliser 2005; Jiang et al. 2008)
- Winkler et al. (2001) suggest improving extratropical predictability by considering tropical diabatic heating ...

1) Subseasonal Prediction & the MJO

The Madden-Julian Oscillation

- The Madden-Julian Oscillation (MJO) is the dominant source of intraseasonal variability in the tropics (30-60 days)



<http://envam1.env.uea.ac.uk/mjo.html>

1) Subseasonal Prediction & the MJO

The Madden-Julian Oscillation

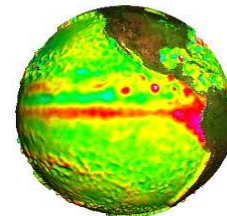
- The MJO is known to influence a myriad of atmospheric phenomena ...
- Monsoons



- Tropical Cyclones



- ENSO



- ... along with the general **extratropical circulation**

1) Subseasonal Prediction & the MJO

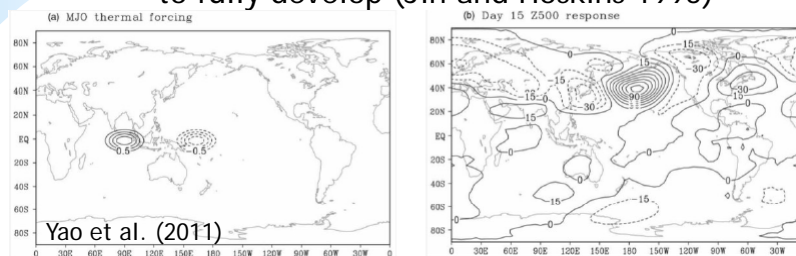
The Madden-Julian Oscillation

- Seeing as the MJO occurs on the subseasonal timescale, it represents a source of predictability for subseasonal forecasting
- The MJO remains underutilized in terms of benefiting medium-to-extended range forecasting and the subseasonal problem (Waliser 2005; Schubert et al. 2002)
- We could improve our forecasts of the MJO. However, there is another way ...

1) Subseasonal Prediction & the MJO

The Madden-Julian Oscillation

- It takes roughly a week for a diabatic heating signal from the tropics to propagate into North America (Lin et al. 2007)
- It takes roughly 2 weeks for the extratropical response to fully develop (Jin and Hoskins 1995)

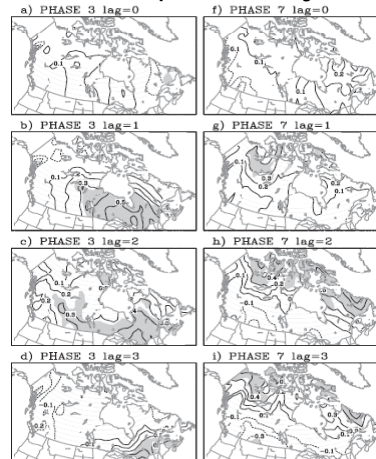


- Yao et al. (2011) used the *current* state of the MJO in a linear regression model to forecast wintertime temperature anomalies over North America

1) Subseasonal Prediction & the MJO

The Madden-Julian Oscillation

- Lin and Brunet (2009) found significant correlations between Canadian wintertime temperatures and the state of the MJO up to 15 days in the past



1) Subseasonal Prediction & the MJO

The Madden-Julian Oscillation

- We seek to extend the work of Yao et al. (2011) by formulating a multi-linear regression model that uses *current* and *past* information of the MJO
 - Attempt to forecast wintertime surface air temperatures (SATs) over North America
 - No need to forecast the MJO

1) Subseasonal Prediction & the MJO

The Madden-Julian Oscillation

- Hopefully a more complete model will demonstrate consistent forecast skill on the submonthly timescale
 - Helps to bridge the gap between extended range weather forecasting and the subseasonal scale
- At the very least may provide a benchmark of some sort for numerical weather prediction models
 - In light of this, we shall also consider the extended range performance of the Global Environmental Multiscale Model (GEM)

1) Subseasonal Prediction & the MJO

Temperature Data

- Daily averaged SAT from the NCEP North American Regional Reanalysis (NARR; Mesinger et al. 2006)
- Daily values averaged into non-overlapping pentad data
 - Winter defined in the DJF sense
 - 1979/1980 - 2008/2009 (30 winters)
- Each winter consists of 18 pentads; total of 540 pentads
 - Seasonal cycle and interannual variability are both removed
 - The result is the intraseasonal variability

2) The Empirical Model

MJO Data

- Real-time Multivariate (RMM) index (Wheeler and Hendon 2004)

(<http://www.bom.gov.au/bmrc/cffor/cfstaff/matw/maproom/RMM/>)

- Empirical Orthogonal Functions (EOFs) based on meridionally averaged OLR and zonal winds at 200 hPa and 850 hPa between 15°S-15°N
- The first 2 Principal Components are used, denoted as RMM1 and RMM2
- Seasonal cycle and interannual variability have already been removed
 - Organized in the same pentad fashion as the temperatures

2) The Empirical Model

The Multi-linear Regression Model

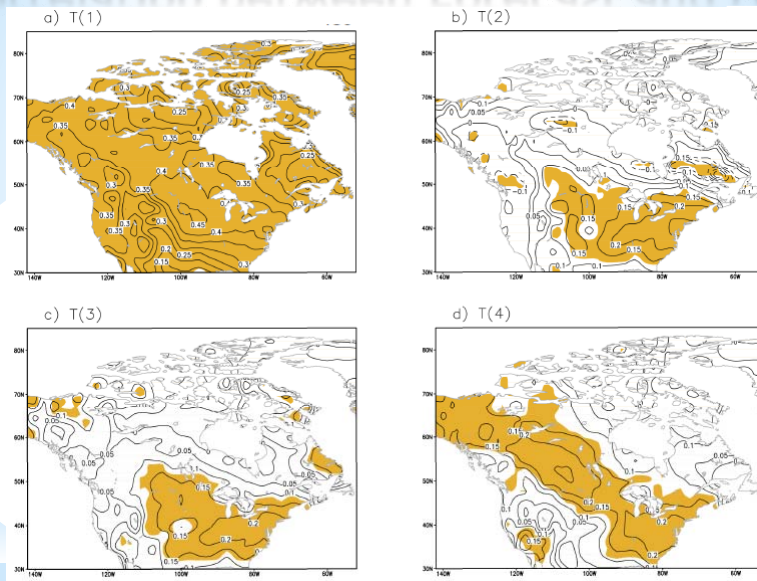
$$T(t) = \alpha_1(t)RMM1(0) + \alpha_2(t)RMM1(-1) + \beta_1(t)RMM2(0) + \beta_2(t)RMM2(-1) + \gamma(t)T(0)$$

$t = 1,2,3,4$ (pentads)

- Cross-validation method
 - 1) Remove one of the 30 winters
 - 2) Train regression model with the remaining 29 winters
 - 3) Apply the model on the neglected winter
 - 4) Repeat until all winters have been forecasted

2) The Empirical Model

Correlation between Forecast and Obs.

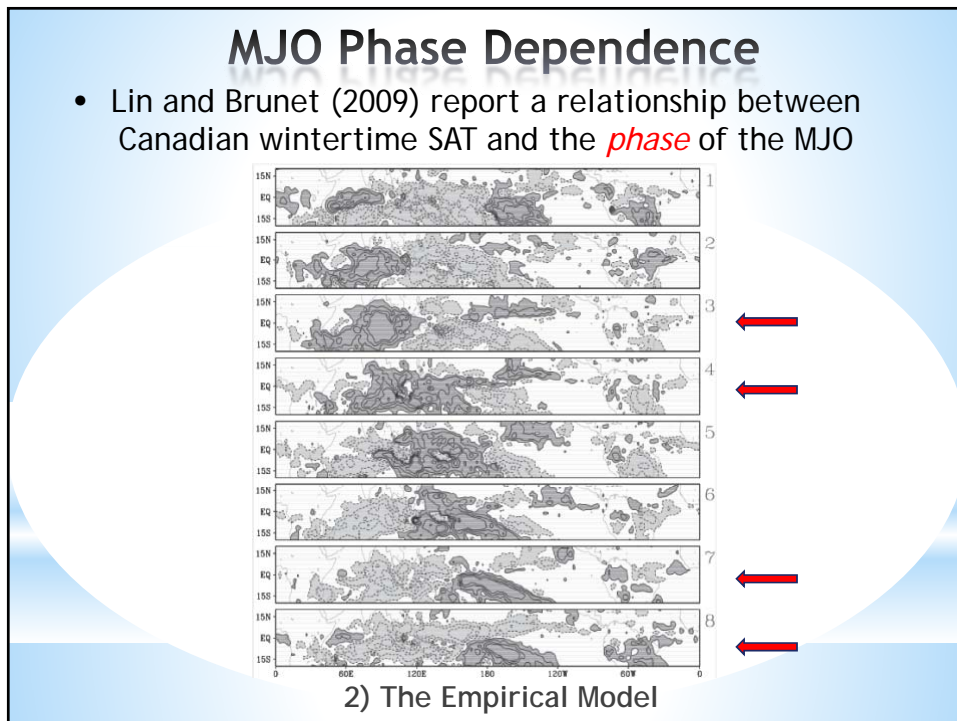
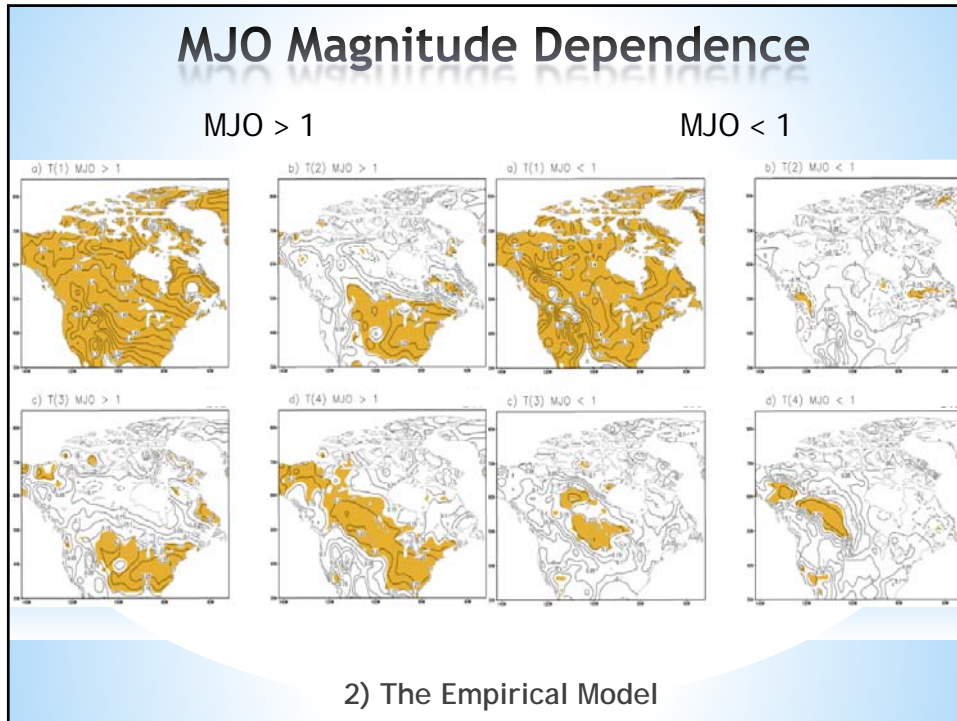


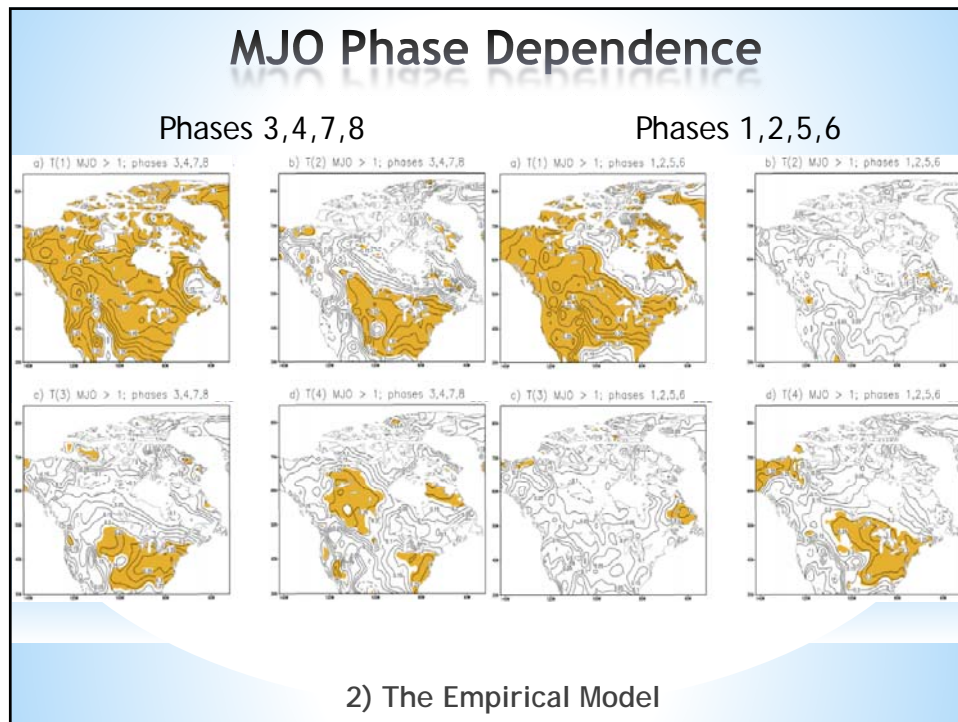
2) The Empirical Model

MJO Magnitude Dependence

$$AMP = \sqrt{(RMM1)^2 + (RMM2)^2}$$

2) The Empirical Model

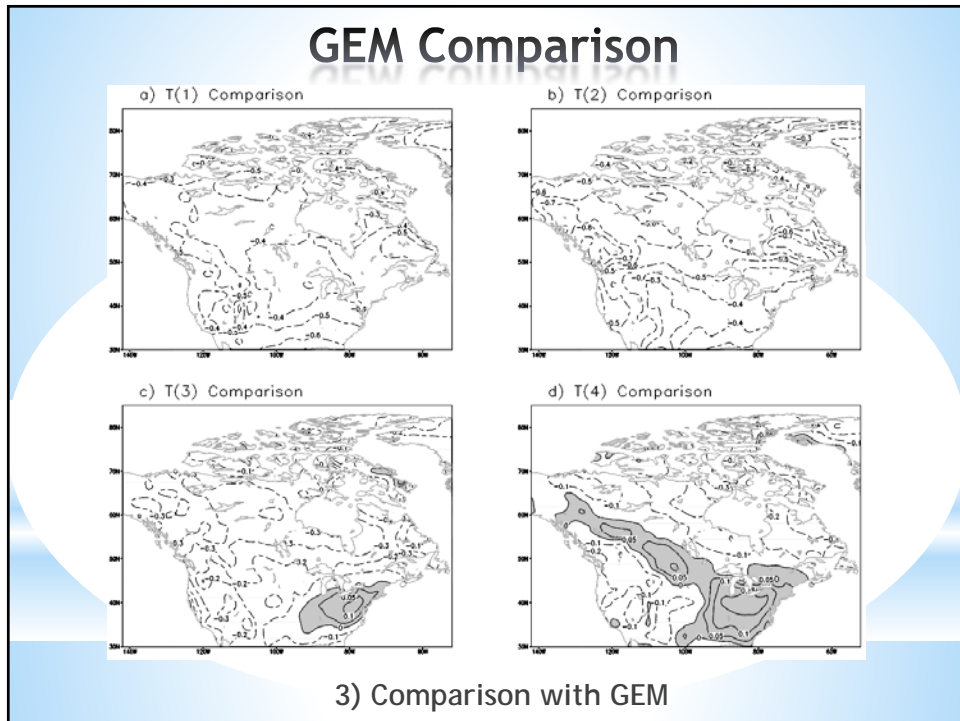
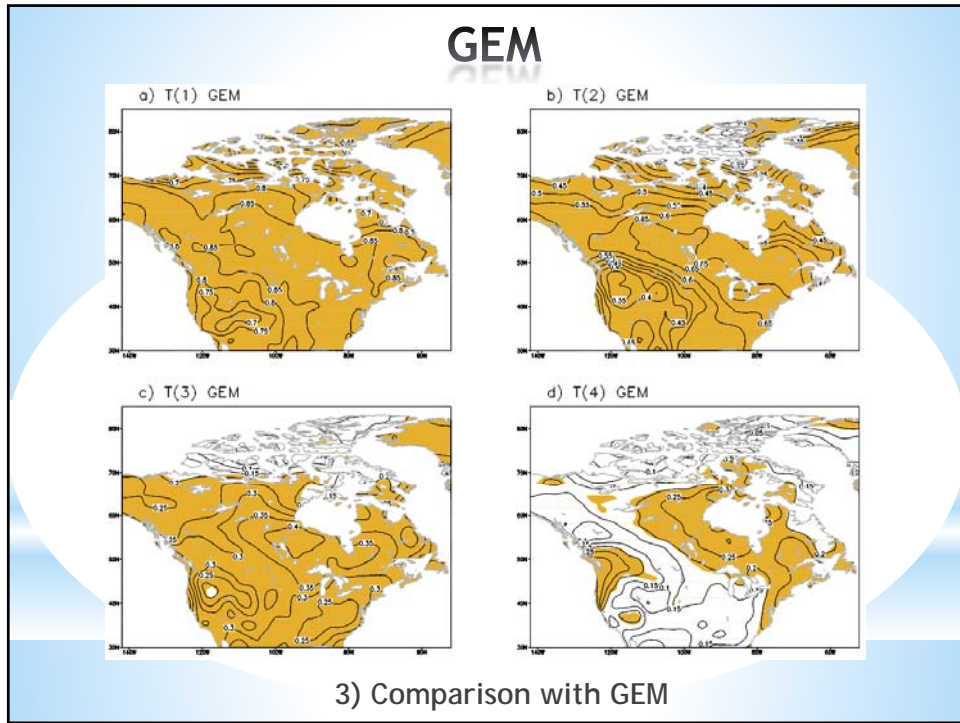


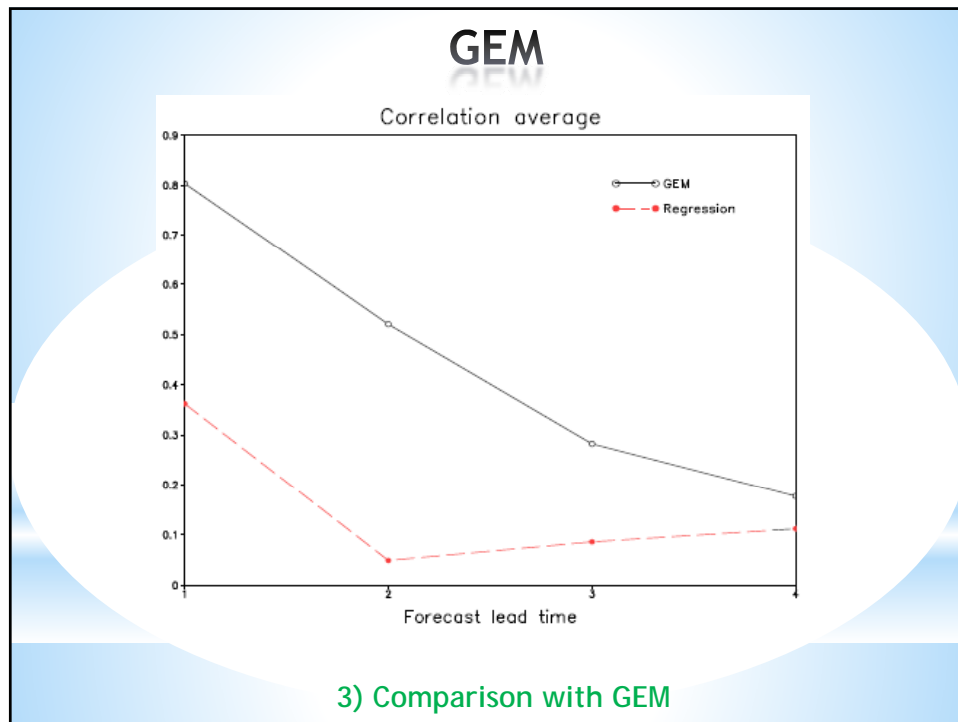


GEM

- Dataset from the Intraseasonal Hindcast experiment
 - 1985 - 2008
 - 10 member ensemble
 - 45 day integrations
- Initial conditions from the global NCEP/NCAR reanalysis (Kalnay et al. 1996)
- SST anomalies persisted from the previous 30 days
- Seasonal and annual cycles have been removed - intraseasonal perturbation
- Analysis done over DJF

3) Comparison with GEM





Summary

- A multi-linear regression model based on the MJO signal was formulated in order to predict wintertime SAT anomalies over North America out to 4 pentads (20 days)
- Statistically significant skill was found mainly over the eastern United States and the Great Lakes
- The model is highly amplitude and phase dependent
- The statistical model was compared to the GEM model
 - Superior skill was mainly seen during the 4th pentad, over the eastern United States

5) Summary

Summary

- This model will hopefully help in bridging the gap between extended range weather forecasting and the subseasonal regime
- Possible forerunner to more sophisticated statistical prediction schemes using the MJO

5) Summary

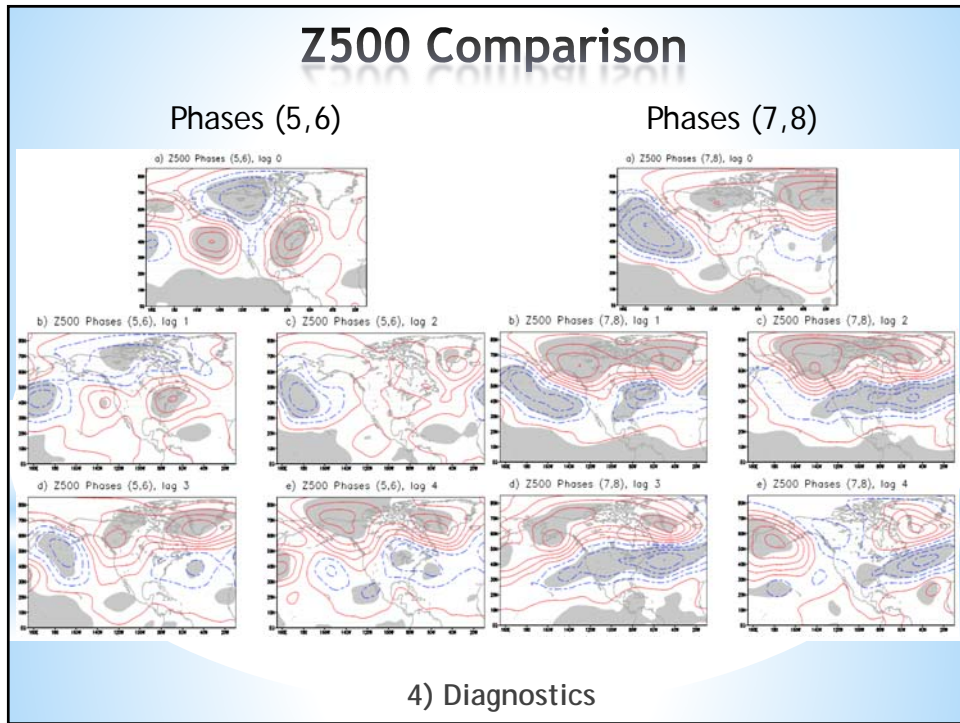
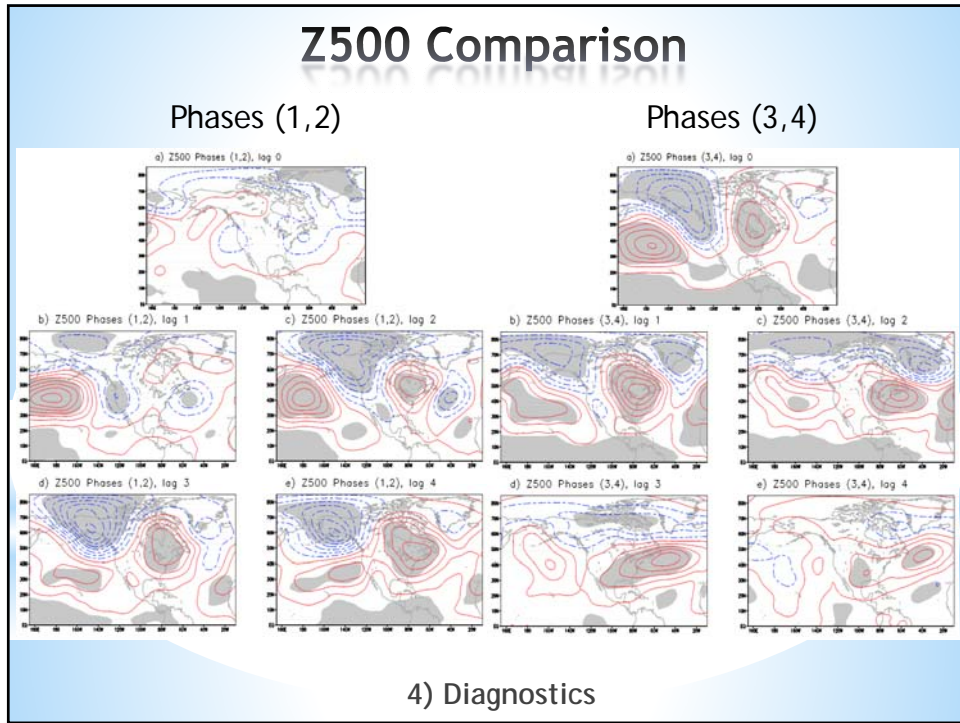
Thank you



Diagnostic Questions

1) What are the dynamics behind the significant phase dependence of the regression model?

4) Diagnostics



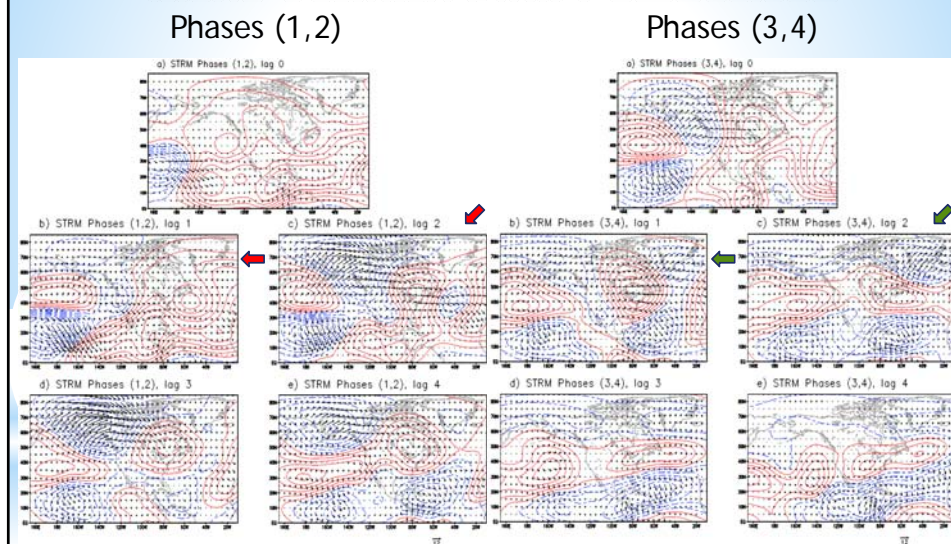
Wave Activity Flux

$$\mathbf{W} = \frac{1}{2U} \begin{bmatrix} U(\psi_x^2 - \psi\psi_{xx}) & V(\psi_x\psi_y - \psi\psi_{xy}) \\ U(\psi_x\psi_y - \psi\psi_{xy}) & V(\psi_y^2 - \psi\psi_{yy}) \end{bmatrix}$$

- Takaya and Nakamura (2001)
- Based on the conservation of wave activity pseudomomentum
 - Tracks wave dispersion

4) Diagnostics

Wave Activity Flux Comparison



4) Diagnostics

Diagnostic Questions

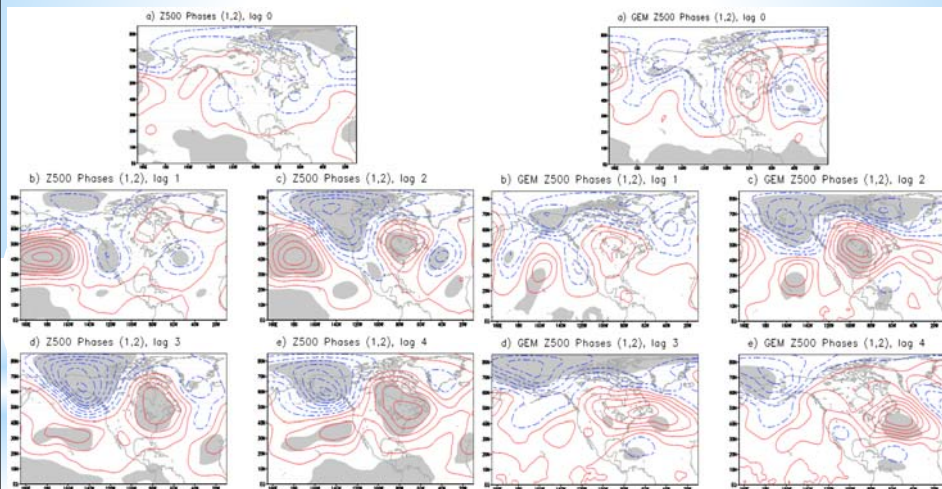
2) How does GEM's extratropical response to the MJO compare to observations?

4) Diagnostics

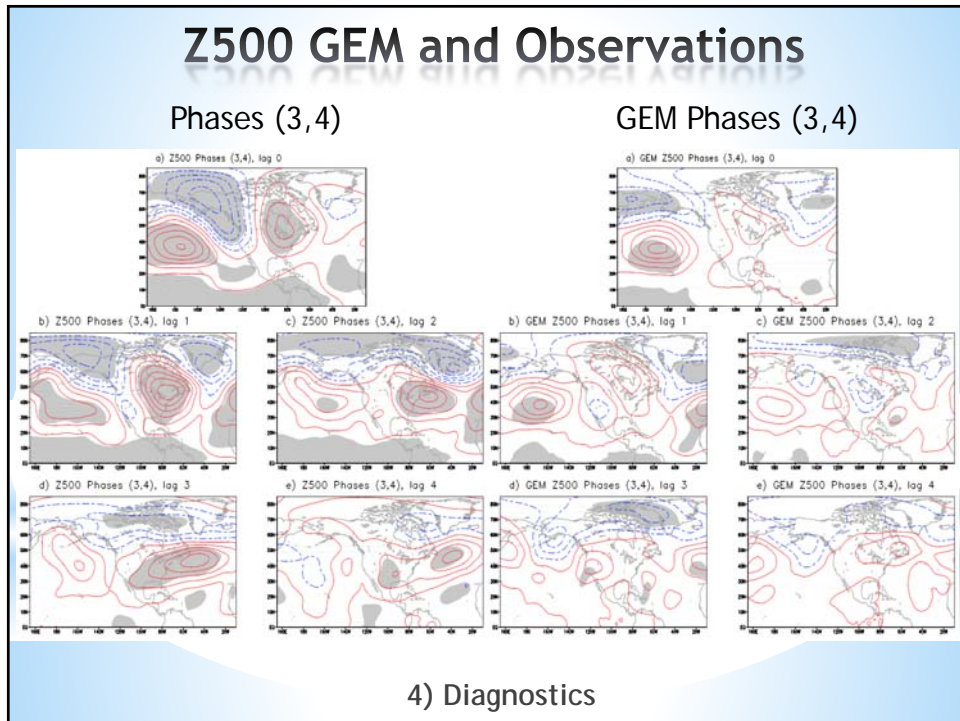
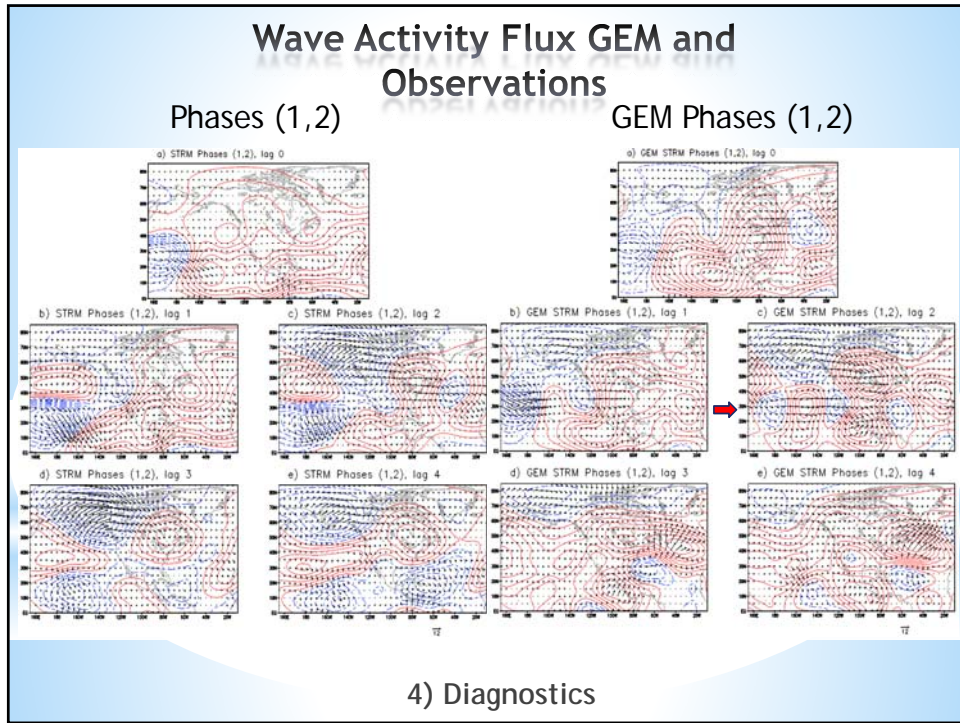
Z500 GEM and Observations

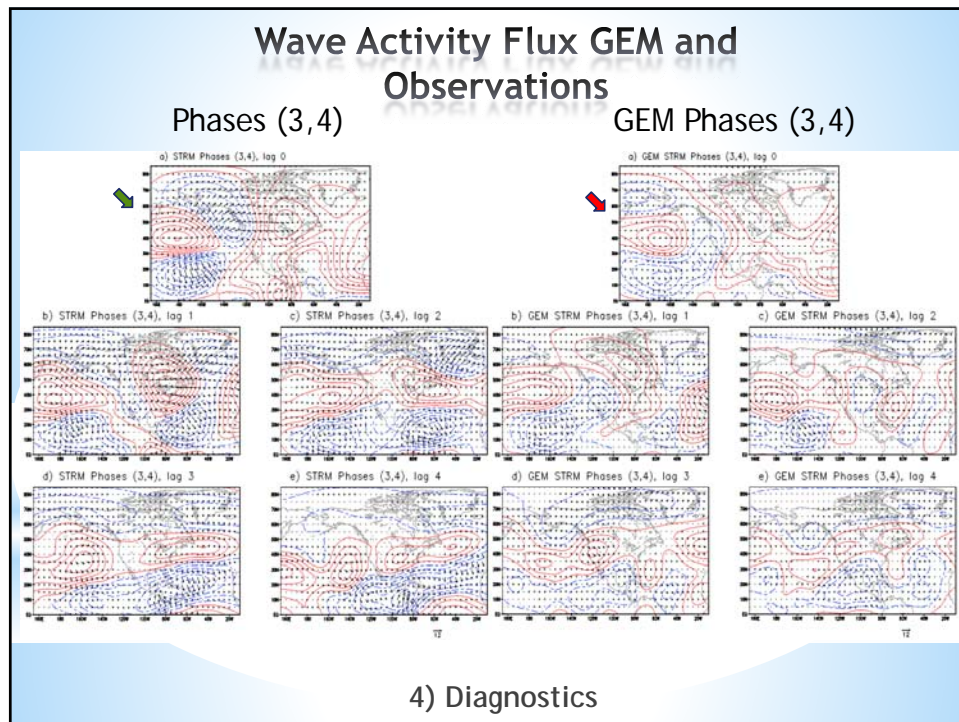
Phases (1,2)

GEM Phases (1,2)



4) Diagnostics



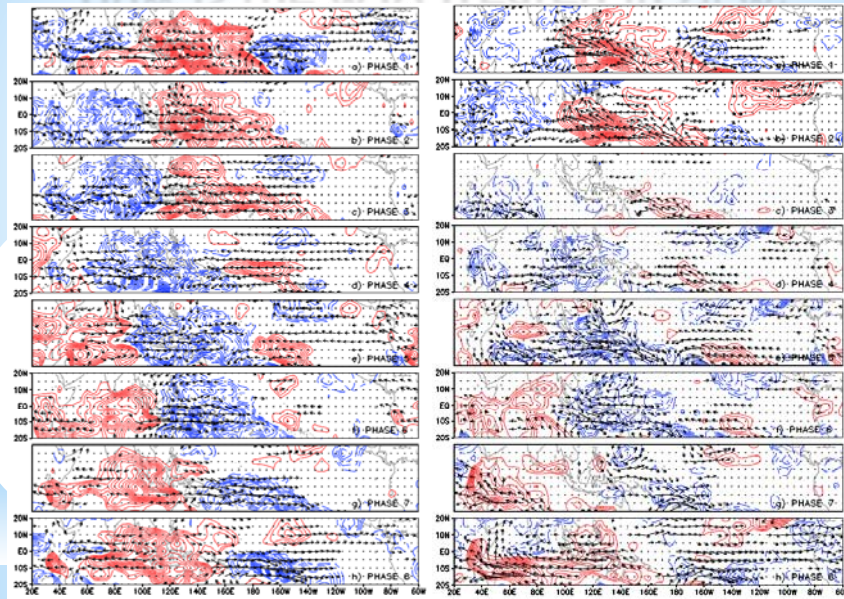


Diagnostic Questions

3) How is the MJO itself depicted in GEM?

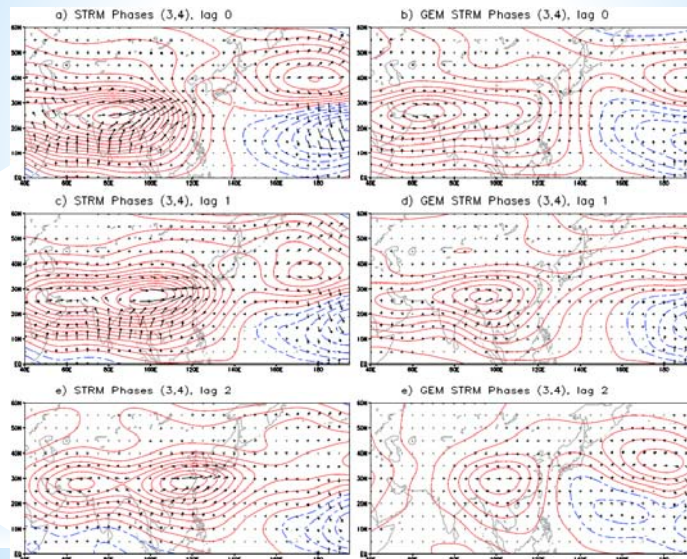
4) Diagnostics

How is the MJO treated in GEM?



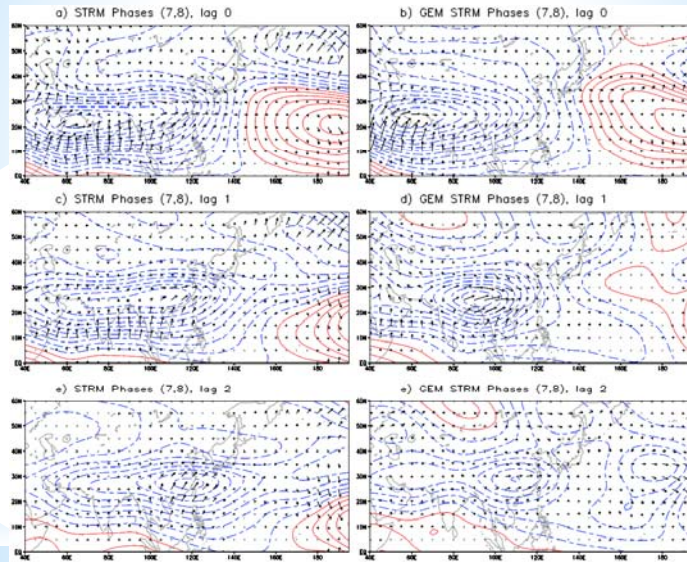
4) Diagnostics

The Matsuno-Gill Response



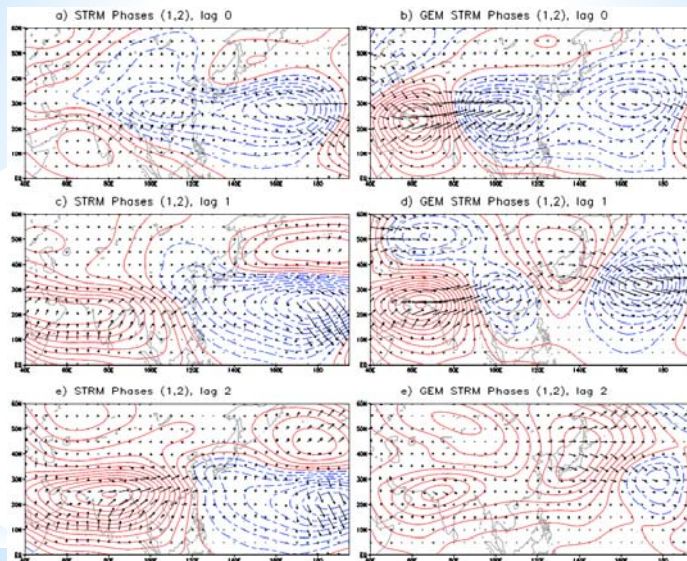
4) Diagnostics

The Matsuno-Gill Response



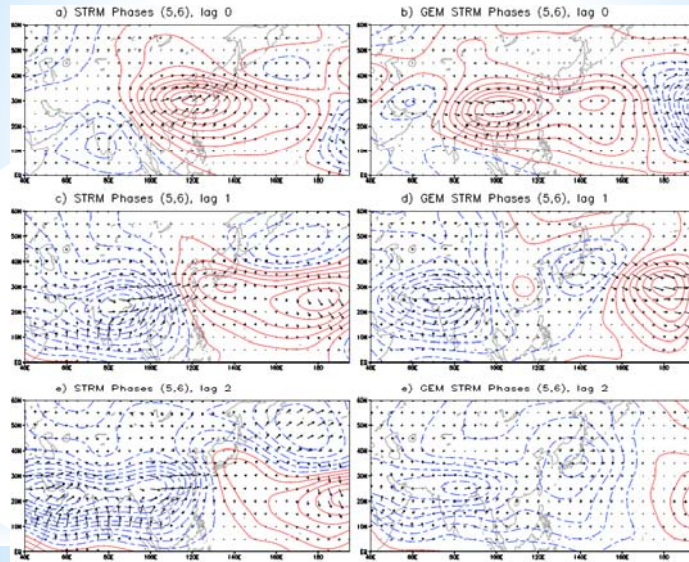
4) Diagnostics

The Matsuno-Gill Response



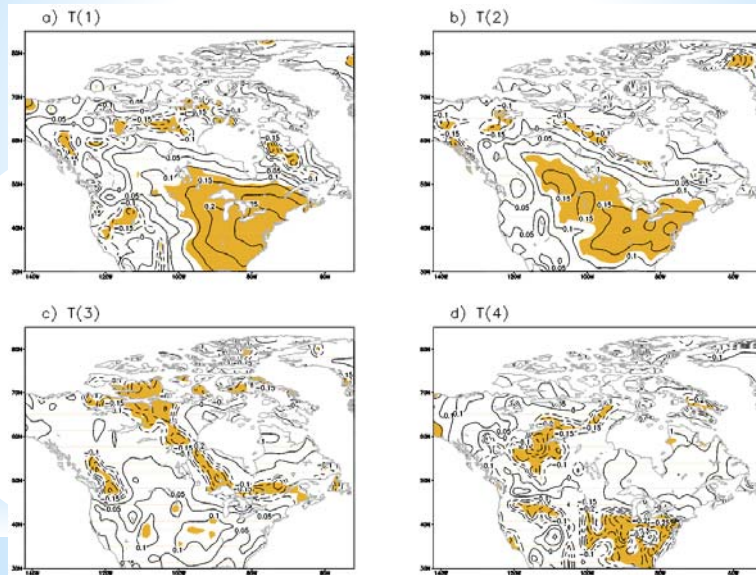
4) Diagnostics

The Matsuno-Gill Response

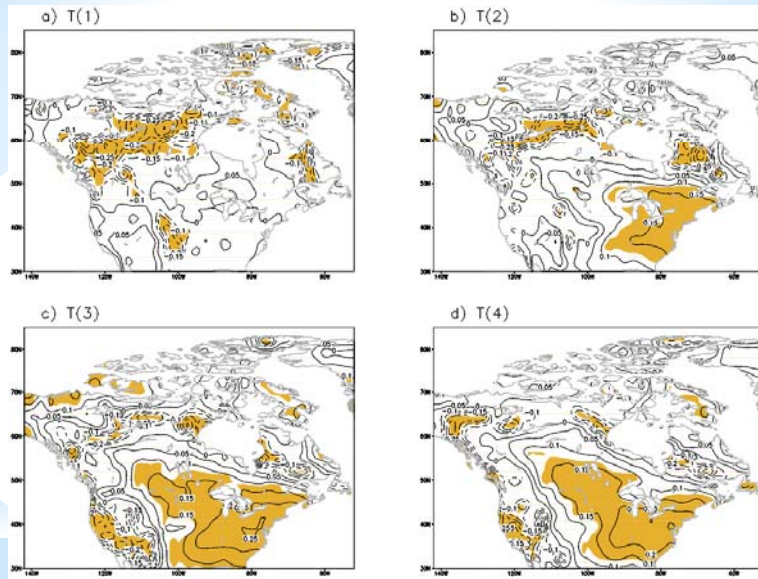


4) Diagnostics

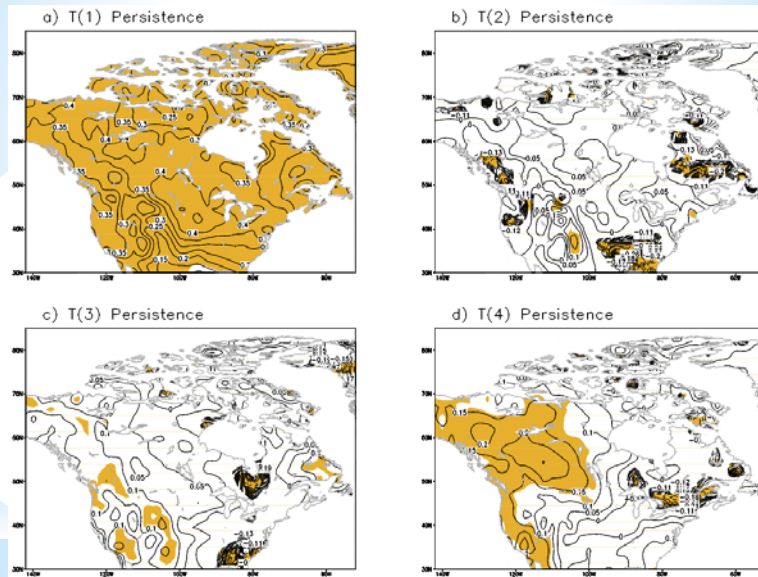
RMM1(0)



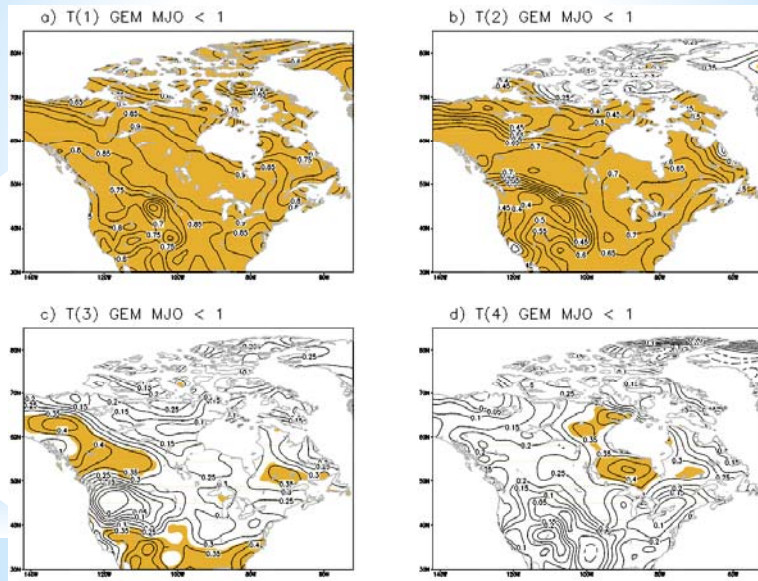
RMM2(0)



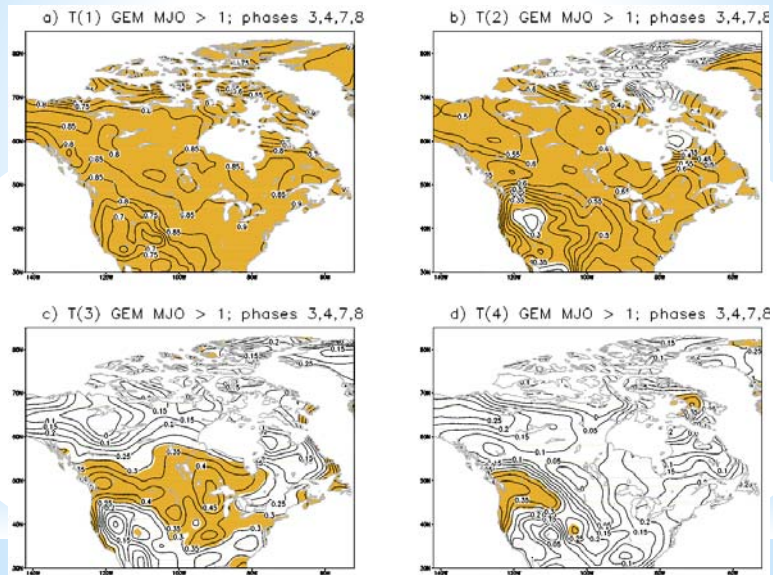
Persistence Term



GEM MJO < 1



GEM phases 3,4,7,8



GEM phases 1,2,5,6

